

Fermi Surface Topology in Na_xCoO_2

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The recent discovery of superconductivity in $\text{Na}_x\text{CoO}_2 \cdot y\text{H}_2\text{O}$ ($T_c \sim 5$ K) has generated great interests. Band structure and Fermi surface (FS) topology are known to be important for understanding unconventional superconductivity. Different electronic structures may induce different fluctuations, which can lead to different pairing symmetries. We reported an angle-resolved photoemission study on $\text{Na}_{0.6}\text{CoO}_2$ single crystals on which we observe clear band dispersion and FS crossings, as shown in Fig. 1. While the observed FS location agrees with the large FS predicted by band theory, the predicted small FS pockets near the K points are not observed, as shown in Fig. 2. In addition, the observed bandwidth is highly renormalized, with a mass renormalization of a factor of 5 - 10, indicating strong many-body interactions in this material.

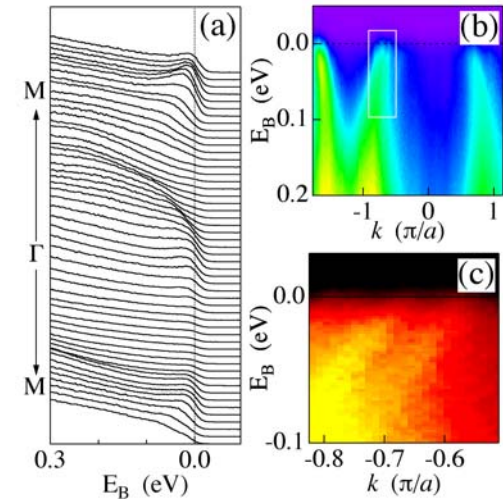


Fig. 1

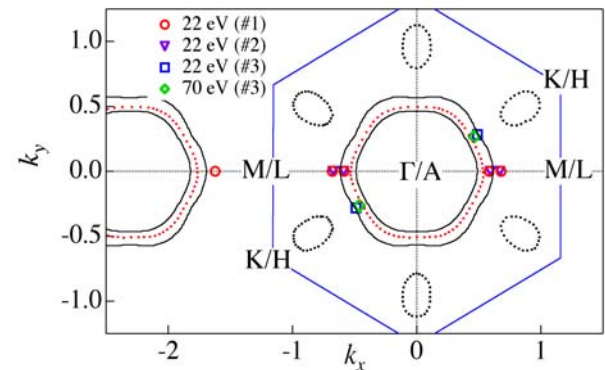


Fig. 2

Over the past 17 years, the study of high temperature (high- T_c) superconductivity has focused on copper oxide compounds (cuprates). The unexpected finding of superconductivity in cobalt oxide (cobaltates) raises the hope that it may help solve the high- T_c problem. Similar to the cuprates, Na_xCoO_2 has a layered structure. However, unlike the cuprates that have a square lattice in the plane, the cobaltate has a hexagonal lattice. Electronically, both compounds have partially filled $3d$ orbitals. In addition to these similarities in the crystal structure and band orbitals, another important connection between the two materials is that both of them have strong on-site Coulomb force, or electron correlation. It is widely believed that the physics of the high- T_c cuprates is closely related to this electron correlation. The study of unconventional superconductors with strong correlations is important to understand high- T_c superconductivity which is regarded by many people as the “holy grail” of condensed matter physics. This work has been published in the June 18, 2004 issue of Physical Review Letters.

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Education

Two undergraduates (P.M. Bishay and F.W. Warren), two graduate students (H.-B. Yang and S.-C. Wang), and one postdoc (A.K.P. Sekharan) have contributed to this work. Both P.M. Bishay and F.W. Warren are freshmen majoring in Physics. S.-C. Wang received his Ph.D. in February 2004 and is now a postdoc in Kevin Smith's group at Boston University. This work is a part of the Ph.D. thesis project of H.-B. Yang who will defend his thesis in December 2004.

Social Impact

The knowledge of band structure and Fermi surface topology is important for understanding unconventional superconductors, such as high temperature superconductors, which have great application potential, including non-dissipating energy transport, high speed computing, and new medical devices.